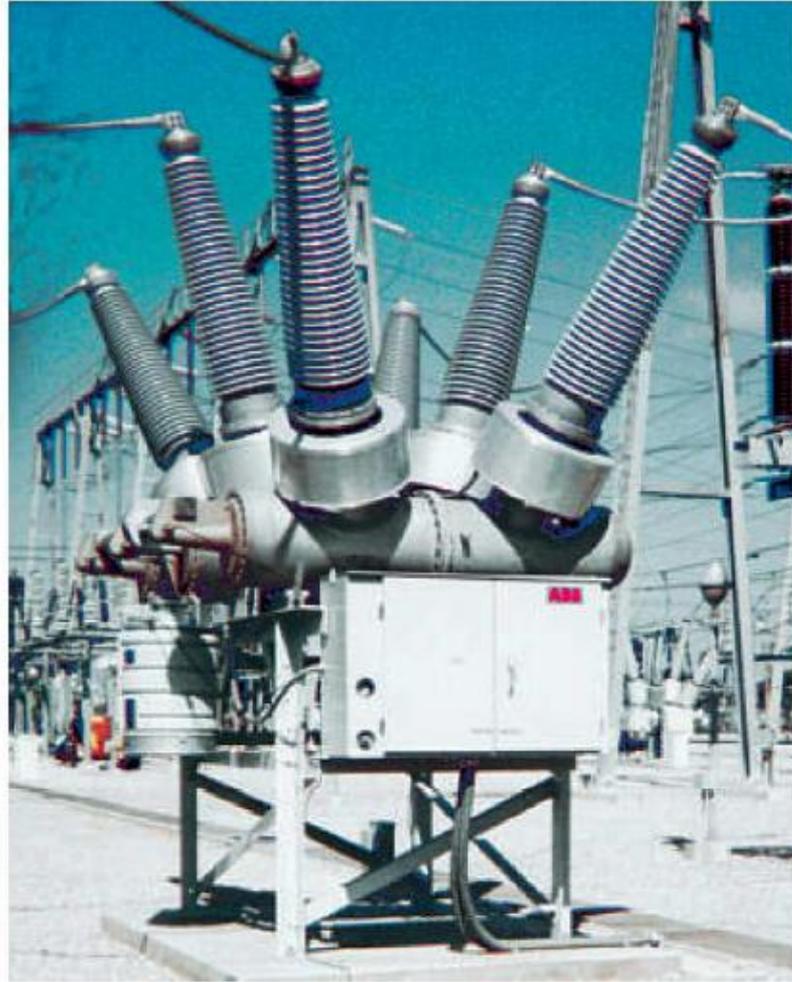


ELG4125: System Protection



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System Protection

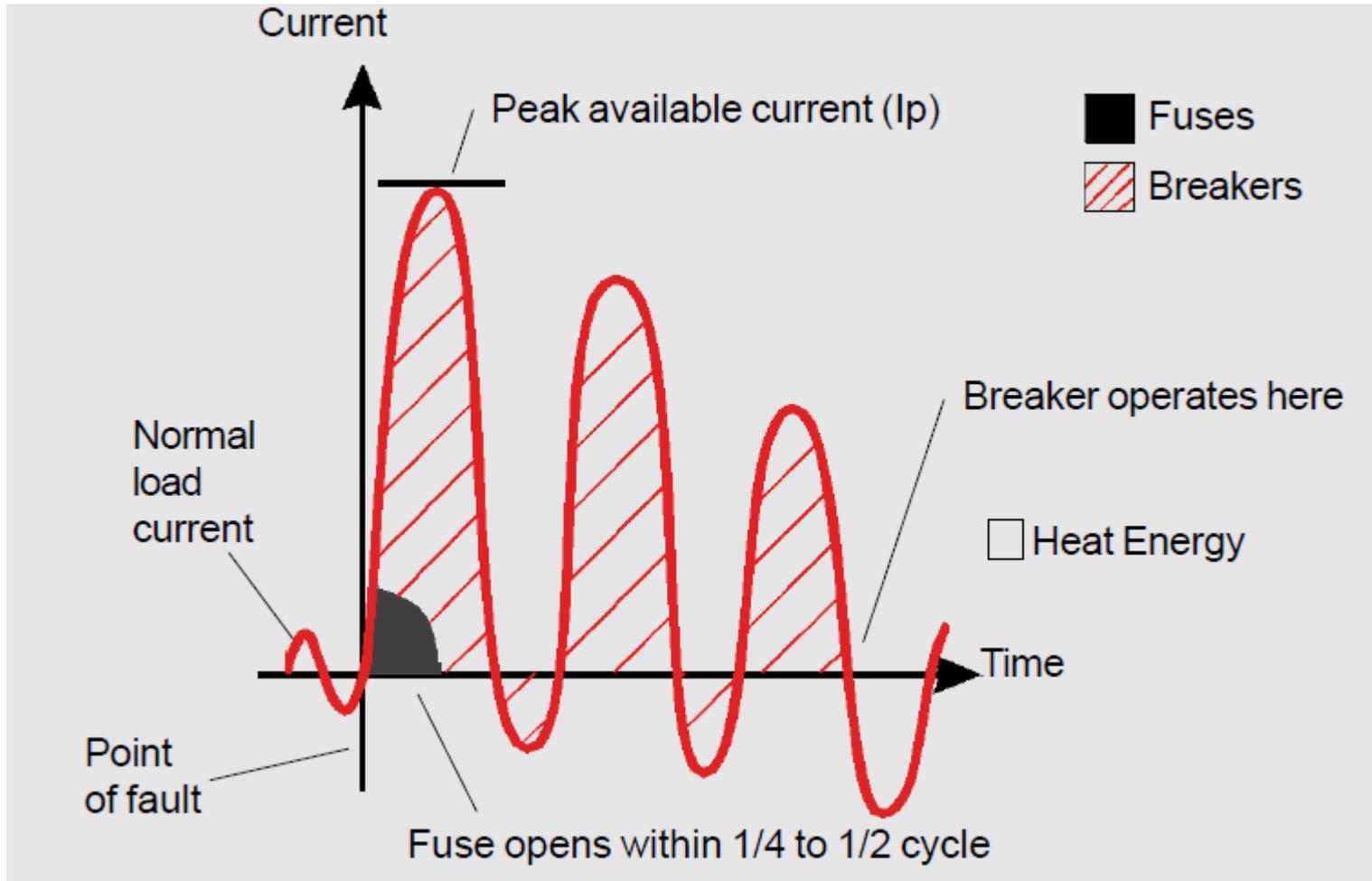
- Any power system is prone to 'faults', (also called short-circuits), which occur mostly as a result of insulation failure and sometimes due to external causes.
- When a fault occurs, the normal functioning of the system gets disturbed. The high current resulting from a fault can stress the electrical conductors and connected equipment thermally and electro-dynamically.
- Arcs at the fault point can cause dangerous or even fatal burn injuries to operating and maintenance workers in the vicinity.
- Faults involving one phase and ground give rise to high 'touch' and 'step' voltages posing danger of electrocution to personnel working nearby. It is therefore necessary to detect and clear any fault quickly.

Sense and Interrupt!

- The first device used in early electrical systems was the fuse, which acted both as the sensor and the interrupting device.
- With larger systems, separate devices became necessary to **sense** and **interrupt** fault currents. In the beginning these functions were combined in a single assembly; a circuit breaker with in-built releases. This practice is still prevalent in low voltage systems.
- In both high systems and low voltage systems of higher capacities, the sensing is done by more sophisticated devices called **relays**.

- With more complex systems, it is necessary to detect the point of fault precisely and trip only those sections affected by the fault while the rest of the system can continue to function normally.
- In the event of the nearest **circuit breaker** failing to operate, the next breaker in the upstream (feeding) side has to be tripped as a 'back up' measure.
- Another requirement is to minimize the time for which a fault remains in the circuit; this is necessary to reduce equipment damage and the danger to operating personnel.
- These requirements necessitate different forms of relaying apart from the simple current sensing relays.
- Equipment such as generators, transformers and motors also need special forms of protection characterized by their design and operating principles.

Fuses and Circuit Breakers



Desirable Protection Facts

- **Reliability:** System operate properly
 - Security: Don't trip when you shouldn't
 - Dependability: Trip when you should
- **Selectivity:** Trip the minimal amount to clear the fault or abnormal operating condition
- **Speed:** The faster the better in terms of minimizing equipment damage and maintaining system integrity
- **Simplicity:** As simple as possible but reliable
- **Economics:** Affordable!

Art of Protection

- Maximum and Reliable protection at minimum equipment cost.
- High Sensitivity to faults and insensitivity to maximum load currents.
- High-speed fault clearance with correct selectivity.
- Selectivity in isolating small faulty area.
- Ability to operate correctly under all predictable power system conditions.
- Cost of protective relays should be balanced against risks involved if protection is not sufficient and not enough redundancy.
- The objectives is to have faulted zone's primary protection operate first, but if there are protective relays failures, some kind of backup protection is provided.

Protection Equipment and Components

- **Transformers:** to step up or step down voltage level
- **Circuit Breakers:** to energize equipment and interrupt fault current to isolate faulted equipment
- **Insulators:** to insulate equipment from ground and other phases
- **Isolators (switches):** to create a visible and permanent isolation of primary equipment for maintenance purposes and route power flow over certain buses.
- **Bus:** to allow multiple connections (feeders) to the same source of power (transformer).

- **Grounding:** to operate and maintain equipment safely.
- **Arrester:** to protect primary equipment of sudden overvoltage (lightning strike).
- **Switchgear:** integrated components to switch, protect, meter and control power flow
- **Reactors:** to limit fault current (series) or compensate for charge current (shunt)
- **Voltage and Current Transformers:** to measure primary current and voltage and supply scaled down values to metering, SCADA, etc.
- **Regulators:** voltage, current, VAR, phase angle, etc.

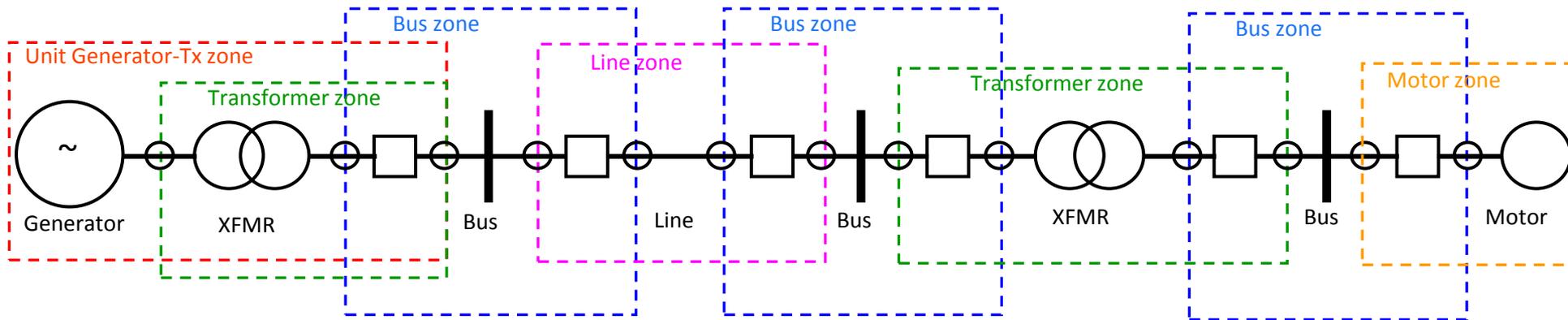
Types of Protection

- **Overcurrent:** It employs current to determine magnitude of fault; simple; slow; inexpensive; relay closest to fault operates first; Relays closer to source operate slower.
- **Differential:** current in should be equal to current out; simple; very fast; very defined clearing area; expensive; practical distance limitations.
- **Voltage:** Uses voltage to infer fault or abnormal condition; may be used for under-voltage load shedding; simple; may be slow; selectivity at the cost of speed; inexpensive.
- **Frequency:** Uses frequency of voltage to detect power balance condition; may employ definite time or inverse time curves; may be slow; selectivity at the cost of speed can be expensive

- **Power:** Uses voltage and current to determine power flow magnitude and direction; complex; may be slow; accuracy important for many applications; may be expensive.
- **Distance:** Uses voltage and current to determine impedance of fault; uses definite time; impedance related to distance; from relay; complicated; fast; somewhat defined clearing area with reasonable accuracy; expensive; communication aided schemes make more selective

Protection Zones

- Generator or generator-transformer units.
- Transformers
- Buses
- Lines (transmission and distribution)
- Utilization equipment (motors, static loads, etc.)
- Capacitor or reactor (when separately protected)

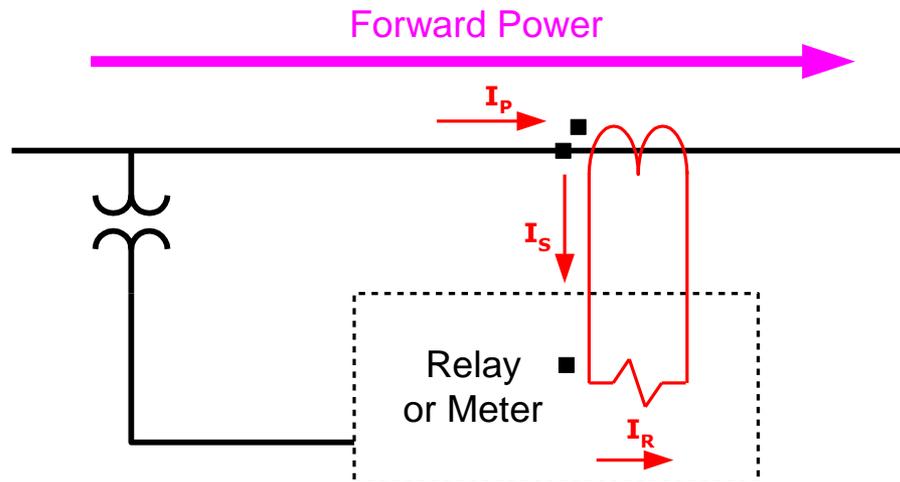


Information Needed to Apply Protection

- One-line diagram of the system or area involved.
- Impedances and connections of power equipment, system frequency, voltage level and phase sequence.
- Existing schemes.
- Operating procedures and practices affecting protection.
- Importance of protection required and maximum allowed clearance times.
- System fault studies.
- Maximum load.
- Voltage and current locations, connections and ratios.
- Future expansion expectance.
- Any special considerations for application.

Equipment: Current Transformers

- Current transformers are used to step primary system currents to values usable by relays, meters, SCADA, transducers, etc. Current transformer ratios are expressed as primary to secondary; 2000:5, 1200:5, 600:5, 300:5!

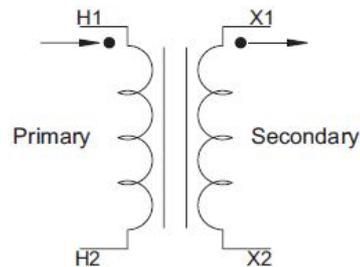


Voltage Transformers

- Voltage (potential) transformers are used to isolate and step down and reproduce the scaled voltage for the protective device or relay. Voltage transformer ratios are typically expressed as primary to secondary; 14400:120, 7200:120.



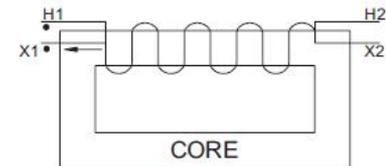
Current Transformer



Current Example
5.5 Amperes
Ratio 1:1



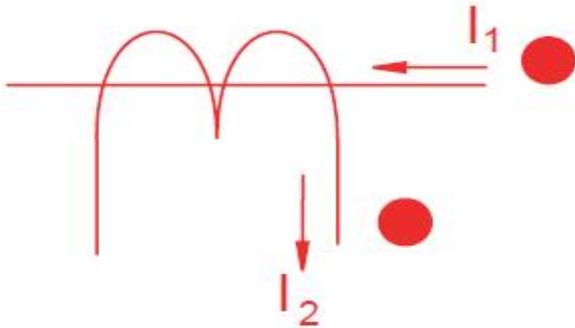
Voltage Transformer



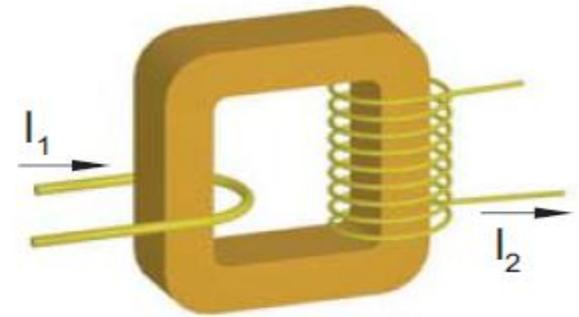
Voltage Example
Primary 7200 Volts
Ratio 60:1 or 7200:120 Volts

Current and Voltage Transformers

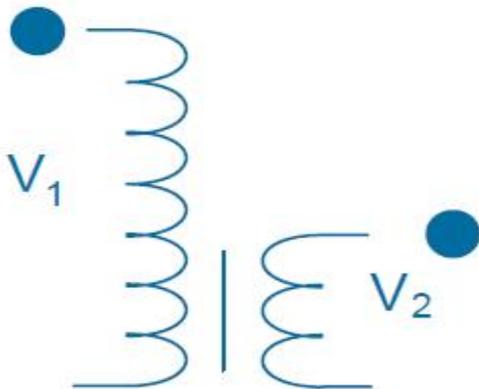
Symbol of a Current Transformer



Conceptual picture of a Current Transformer



Symbol of a Voltage Transformer



Conceptual picture of a Voltage Transformer



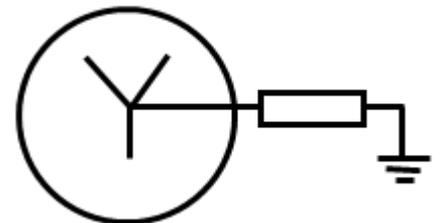
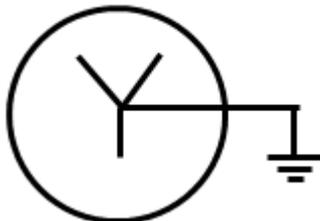
Grounding

Equipment Grounding:

- Prevents shock exposure of personnel.
- Provides current carrying capability for the ground-fault current.
- Grounding includes design and construction of substation ground mat and current/voltage transformer safety grounding.

System Grounding:

- Limits over-voltages
- Limits difference in electric potential through local area conducting objects
- Several methods:
 - **Ungrounded:** Only through natural capacitance!
 - **Reactance coil Grounded:** Decreases the current at the fault and limits voltage across the arc at the fault to decrease damage.
 - **High Z Grounded:** Limits ground fault current to 10A-20A. Used to limit transient over-voltages due to arcing ground faults.
 - **Low Z Grounded:** To limit current to 25-400A.
 - **Solidly Grounded:** There is a connection of transformer or generator neutral directly to station ground.

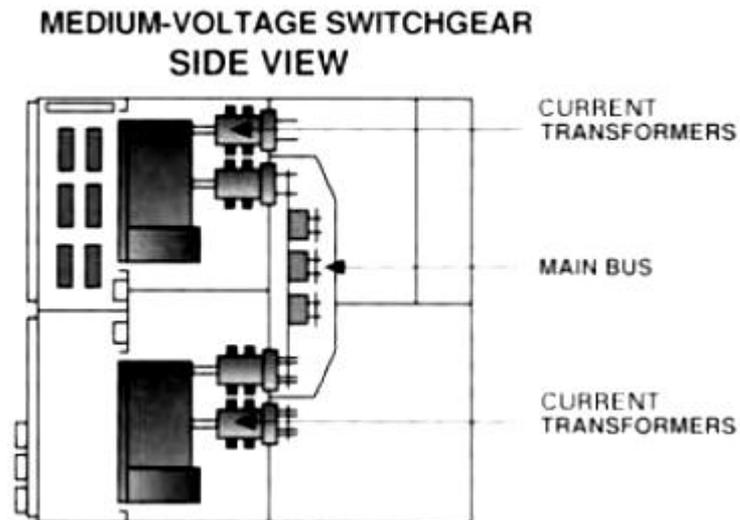


Switchgear

- Assemblies containing electrical switching, protection, metering and management devices.
- Used in three-phase, high-power industrial, commercial and utility applications.
- Covers a variety of actual uses, including motor control, distribution panels and outdoor switchyards.
- The term "switchgear" is plural, even when referring to a single switchgear assembly (never say, "switchgears")
- May be described in terms of use: generator switchgear; stamping line switchgear.
- All Switchgear has a metal enclosure.
- Metal-clad construction requires 11 gauge steel main compartments.
- Prevents contact with live circuits and propagation unlikely event of an internal fault.



- Equipment such as circuit breakers or fused switches provide protection against short circuits and ground faults.
- Interrupting equipment (other than fuses) are non-automatic. They require control signals instructing them to open or close.
- Monitoring and control circuitry work together with the switching and interrupting devices to turn circuits on and off, and guard circuits from degradation or fluctuations in power supply that could affect or damage equipment.
- Metering functions include operating amperes and voltage, watts, kilowatt hours, frequency, power factor.



Correct and Wrong!

- **Correct: Above 90%**
 - CTs and VTs bring electrical info to relays.
 - Relays sense current and voltage and declare fault.
 - Relays send signals through control circuits to circuit breakers.
 - Circuit breaker(s) correctly trip.
- **Wrong: Below 10%**
 - CTs or VTs are shorted, opened, or their wiring is bad.
 - Relays do not declare fault due to setting errors, faulty relay, CT saturation.
 - Control wires cut or batteries dead so no signal is sent from relay to circuit breaker.
 - Circuit breakers do not have power, burnt trip coil or otherwise fail to trip.

Instrument Transformer Connection

